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REVIEWS

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.

WINCHELL[1] discusses the general structural geology of northeastern Minnesota. The ancient rocks of this area he places in two main systems, the Archean and the Taconic. The former is further subdivided into the Upper and Lower Keewatin, separated from each other by an unconformity. The Pewabic quartzite also is placed with the Keewatin, but is not assigned to either of the main divisions. Overlying the Archean with strong unconformity is the Taconic, represented by Animikie and Keweenawan rocks, these divisions being supposed to represent respectively the Lower and Middle Cambrian of other parts of the country. The Coutchiching and Laurentian rocks before mapped as separate formations are now included within the Keewatin.

The Lower Keewatin comprises greenstone, with associated surface volcanics which are both subaërial and subaqueous, argyllitic slates, siliceous schists, quartzites, arkoses, "greenwackes," iron ores, and marble.

[1] The Geology of Minnesota, by N. H. WINCHELL, U. S. GRANT, JAMES E. TODD, WARREN UPHAM, and H. V. WINCHELL: Final Rept. of the Geol. and Nat. Hist. Surv. of Minnesota, Vol. IV, 1899, pp. 630. With thirty-one geological plates.

Structural geology of Minnesota, by N. H. WINCHELL: Final Rept. Geol. and Nat. Hist. Surv. of Minnesota, Vol. V, 1900, pp. 1–80, 972–1000.

The first of these volumes contains an account of detailed field work in northeastern Minnesota, with incidental discussion of general problems. The area is treated by counties and smaller arbitrary geographical divisions, in the description of which several men have taken part. This manner of treatment leads to repetition in the discussion of the general geological features, and in many cases it is extremely difficult to correlate the facts recorded in the different sections.

Volume V contains an account of the general structural geology of the state by Professor Winchell based on the detailed work described in Vol. IV. This general discussion of Vol. V is reviewed, with such reference to the facts recorded in Vol. IV as is necessary to make the summary intelligible.

Dr. Grant's views, as indicated in the detailed descriptions of special areas, in some cases differ somewhat widely from those of Professor Winchell.

The greenstone, designated the Kawishiwin, is the oldest known rock in the state, and is supposed to represent a portion of the original crust of the earth. With its associated volcanic rocks it occurs in two main belts. The southern belt begins in the vicinity of Gunflint Lake and extends westward by way of Gobbemichigamma Lake, the Kawishiwi River, and White Iron Lake, to Tower, and indefinitely westward. The northern belt of greenstone enters the state from Hunters' Island, appearing conspicuously at the south side of Basswood Lake. At Pipestone Rapids and Fall Lake it widens southward and apparently unites at the surface with the southern belt, the overlying Upper Keewatin being absent for a distance of a few miles. But further west it is again divided by the Stuntz conglomerate, the northern arm running to the north of Vermilion Lake, west of which its extension is unknown, and the southern one running south of the lake.

The fragmental stratified rocks of the Lower Keewatin are most important toward the western part of the area of exposure of crystalline rocks. They occupy a wide area, south, west, and north of Tower. The iron ores of Tower and Ely on the Vermilion iron range occur in the upper part of the Lower Keewatin. It is probable that the immediately enclosing rock is a sedimentary one, although composed of the elements of a basic eruptive. The sediments extend south to the Giants Range of granite, where they are metamorphosed to mica-schists by the granite. Toward the west they extend as far as the Mississippi River and its northern tributaries and across the Bowstring, although the drift prevents the delimitation of the belt. To the northwest they extend toward Rainy Lake, in this direction being converted into mica-schists and gneisses by the intrusion of granite; in unmodified form they are found at one point only on Rainy Lake. These fragmental rocks of the Lower Keewatin doubtless also underlie most of the central and southwestern part of the state as far as the Minnesota River. Here they dip beneath the later formations in the southwestern portion of the state, and probably occupy a wide patch in South Dakota. South of the Giants Range they occur also, but as they are covered by the gabbro and Animikie toward the east and the drift deposits of the St. Louis valley toward the west their geographic boundaries are mostly unknown. They appear in the central and western portions of Carlton county, where their line of separation from the Upper Keewatin is quite obscure, and in the central and western portions of Morrison county. The Lower Keewatin marble is seen at Lake Ogishke-Muncie and at Pike Rapids on the Mississippi.

The Lower Keewatin was terminated by a period of extensive folding and intrusions of granite and basic rocks.

The Pewabic quartzite belongs with the Keewatin, but whether to the Lower or Upper Keewatin is not known. This formation includes altered quartzites and iron-ores between the granite and gabbro in the immediate vicinity of Birch Lake and small patches of similar rocks in Sec. 30–62–10; on the south shore of Disappointment Lake; on the north shore of Fraser Lake; on the south shore of Gabbemichigamma; at Akley Lake, forming the so-called Akley Lake series extending from the west side of Sec. 34–65–5 to the eastern part of Sec. 27–65–4.

The Upper Keewatin occurs in troughs in the Lower Keewatin, and particularly in one main trough the axis of which is traceable from Vermilion Lake to Saganaga Lake. The northern arm of this syncline, consisting of granites, gneisses, associated mica-schists, and in some places earlier greenstones, extends from the northern part of Vermilion Lake through Basswood Lake to the northern side of Hunter's Island. The southern arm, consisting of Lower Keewatin green-schists and other schists, penetrated by the granite of the Giants Range, extends from Pokegama Falls on the southwest toward the northeast, until cut out by the encroachment of the gabbro from the south. The Upper Keewatin consists very largely of conglomerates, but also includes graywackes, argyllites, quartzites, and jaspilites, in general coarser than those of the Lower Keewatin. Volcanic rocks are less important than in the Lower Keewatin, although still present. There is no general order of succession in the Upper Keewatin excepting that it can be said that it is in general conglomeratic at the bottom.

After Upper Keewatin time both the Lower and Upper Keewatin were subjected to another folding, the axis of which had a general parallelism with the earlier folding, with the result that the Upper Keewatin lies in narrow synclines in the Lower Keewatin and in places is nearly or quite vertical.

Associated with the Keewatin rocks are granites of at least two periods of intrusion, one later than the Lower Keewatin and one later than the Upper Keewatin. The later granite is believed to be represented by the higher parts of the Giants Range and the Snowbank Lake granite. The earlier granite is represented by the granites at Kekequabic Lake, Saganaga Lake, Basswood Lake, Burntside Lake, Vermilion Lake, Lac la Croix, and Kabetogoma Lake. The origin of the granite is discussed and the same conclusions reached as in a previous article.[1]

The Taconic.—This is unconformably above the Keewatin rocks. It comprises the Animikie and Keweenawan divisions.

The Animikie rocks enter the state at Pigeon Point, run westward along the international boundary to the eastern part of Secs. 22 and 27 T. 65 N., R. 4 W. They reappear again southwestward from Birch Lake on the northwest side of the gabbro mass, and thence continue along the south side of the Giants Range, constituting the Mesabi iron series, to Pokegama Falls. The higher parts of the Animikie are best developed toward the east, while the lower parts are best developed toward the west.

The Animikie rocks comprise the Pokegama quartzite, Mesabi iron-bearing formation, some limestone and slate, all strictly conformable with one another. The thickness is several hundred feet, sometimes reaching nearly 1000 feet. The dip of the series is uniformly to the south, 8° to 12°.

The iron-bearing formation and the Pokegama quartzite constitute the base of the formation. The quartzite in places is beneath the iron formation; in other places it is in the same horizon; and in still others is above the iron formation. Commonly the base of the Animikie is marked by a conglomerate, containing débris from the underlying Keewatin rocks. This is a narrow horizon which soon graduates upward into a quartzite, known as the Pokegama quartzite, from its typical development near Pokegama Falls on the Mississippi River. The thickness of the quartzite is not known to exceed fifty feet, and is sometimes less than twenty-five feet.

Above the quartzite, or in alternating beds with it, or below it, appears the iron-bearing or taconyte member of the Animikie, which contains the iron ore deposits of the Mesabi iron range. The ore is usually hematite in the western part of the range and magnetite in the eastern part. It was previously supposed to have been derived from the alteration of a greenish glauconitic sand-rock; but later work has seemed to show that the green-sand is a volcanic sand, and that the so-called taconitic rock itself has resulted from igneous forces. This is accounted for by supposing a chain of active volcanoes to have existed where the Mesabi iron range is now found. These volcanoes yielded flows and ejectamenta to the adjacent waters which have been modified into the various phases of the iron formation now seen. This volcanic epoch may have a deep-seated connection with the Cabotian or lower division of the Keweenawan (described later).

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[1] The origin of the Archean Igneous Rocks, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci., Vol. XLVII, 1898, pp. 303, 304 (Abstract). Also Am. Geol., Vol. XXII, 1898, pp. 299-310. Summarized JOUR. GEOL., Vol. VII, 1899, p. 194.

Above the iron-bearing member is an impure dark colored limestone a few feet in thickness, not exceeding twenty. It extends apparently the whole length of the Mesabi range, but has been identified in two places only, Sec. 7, T. 58 N., R. 17 W., and doubtfully on the shores of Gunflint Lake. This limestone may be regarded as the basal horizon of the next overlying rock.

The black slate is probably several thousand feet in thickness and constitutes the bulk of the Animikie. In the neighborhood of Gunflint Lake it has been divided by Dr. Grant into a lower black slate division and an upper graywacke-slate division, both of which members are interleaved with diabase sills.

In the Indian reservation at Grand Portage and at various places along the Grand Portage trail is a graywacke, which is supposed to overlie the black slate member, but its extent and stratigraphical position have not been satisfactorily established.

The top of the Animikie has not been identified. The first recognizable datum plane after the close of the Animikie is the Puckwunge conglomerate, supposed to be the fragmental base of the Keeweenawan.

At one or two places southwestward from Birch Lake, and at Little Falls on the Mississippi River, and in Morrison county, the Animikie has been converted into a mica-schist.

The age of the Animikie is believed to be Lower Cambrian for the following reasons: It graduates upward into Upper Cambrian rocks as seen on the south side of Lake Superior. The derivation of the iron ores from a glauconitic green-sand indicates that large quantities of foraminiferal organisms once lived in the Animikie ocean, and Matthew has shown the existence of foraminiferal organisms associated with the iron ore in the St. Johns group of New Brunswick. Further the Animikie has a uniformly low dip, while the lower strata are all highly tilted. There must therefore have been a great lapse of time between the deposition of the two series.

The Keweenawan.—The Puckwunge conglomerate is taken to be the *fragmental* base of the Keweenawan, although certain igneous rocks which antedate it and which perhaps are contemporaneous with the upper portions of the Animikie are also called Keweenawan. The conglomerate is found at Grand Portage Island, at Isle Royale, on the Baptism River, at Little Marais, on Manitou River, at the deep well at Short Line Park near Duluth, and at New Ulm.

Above this conglomerate are conglomerates and sandstones of Keweenawan age which are stratified with lavas of diabasic nature. Still higher up the eruptive rocks become less in quantity and the fragmental rock is a sandstone, known as the Hinckley sandstone, quarried in the gorge of the Kettle River in Pine county. This in turn grades up into typical Upper Cambrian sandstones of the St. Croix valley. The term Potsdam is restricted to the Puckwunge conglomerate and the hardened quartzites immediately overlying it, represented by the Sioux quartzite, the Baraboo and Barron county quartzites of Wisconsin, the quartzite at Grand Portage Island, and west of Grand Portage village, the New Ulm quartzite in Cottonwood county, and the quartzite in Pipestone county.

The igneous rocks of the Keweenawan vary in age from the late Animikie time to the top of the Keweenawan series. They are divided into two groups, the Cabotian or Lower Keweenawan, and the Manitou or Upper Keweenawan.

The Cabotian division includes gabbro and contemporaneous red rock and their surface lavas, and all other dikes and sills which are associated with, but younger than, the Animikie clastic rocks, and which are older than the Puckwunge conglomerate. The lower member of the Cabotian is the gabbro, which covers an enormous area. It extends on the east to East Greenwood Lake in T. 64, N., R. 2 E. On the north it is bounded by the Animikie strata of the Mesabi iron range. Its westernmost exposure is in the vicinity of Short Line Park, Duluth. The southern limit is irregular, swinging from East Greenwood Lake in a zigzag manner through T. 63 N., R. 1 W., T. 62 N., R. 2 W., T. 62 N., R. 4 W., T. 60 N., R. 6 W., T. 60 N., R. 7 W., T. 58 N., R. 10 W., and T. 55 N., R. 11 W., to Duluth.

Along the northern and northwestern side of the great gabbro mass, the gabbro is plainly intrusive on the older formations, Animikie and Keewatin.

From the northern border of the gabbro many sills offshoot and penetrate the Animikie strata parallel to the bedding. These are known as the Logan sills.

Near its contact with the underlying rocks, both the Animikie and Keewatin series, there are various altered rocks which can be connected in places with the gabbro and in places with the underlying rocks. To these altered rocks the term muscovadyte has been applied. It includes the various so-called peripheral phases of the gabbro.

On the southern and eastern border the gabbro is penetrated by and penetrates in a confused manner the red rock, with which it alternates both structurally and areally. It is believed to have resulted from the metamorphism by the gabbro of the Animikie, and perhaps earlier fragmentals.

As the granites of the Archean are believed to have resulted from the softening of acid fragmentals, so the gabbro may probably have been the result of the metamorphism or re-fusion of the Keewatin greenstones.

The anorthosite masses of the Beaver Bay diabase, supposed by Lawson to be of Archean age and to underlie unconformably the Beaver Bay diabase, are believed to represent segregation phases in the main gabbro flow, and to be the same as anorthosite masses in the gabbro proper to the west.

The Beaver Bay diabase is believed to represent the upper portion of the great gabbro flow, and to be due to the first and greatest movement of the gabbro toward Lake Superior. The Logan sills belong to this part of the gabbro flow.

The Manitou division of the Keweenawan includes the surface flows, sills, and dikes which accompanied and followed the Puckwunge conglomerate. These eruptives, with the clastics associated with them, do not have a thickness in Minnesota of more than 1000 feet. These lava sheets extend along the shore of Lake Superior from near Baptism River to near Grand Marais, except where replaced at intervals by the Beaver Bay diabase or some of the intersheeted fragmentals. They occur also in the neighborhood of Grand Portage Bay, but their extent here is not definitely known.

General.— The most important petrological conclusions determined from the examination of the Minnesota crystalline rocks, are three in number:

1. All the granites of the Archean can be explained on the assumption that they are intrusives representing the metamorphosed conditions of clastic rocks adjacent to the observed intrusions, rendered plastic by the force of dynamic metamorphism accompanied by moisture.

2. The basic Keweenawan gabbro and its derivatives are derived from the metamorphism and complete re-fusion of the Archean greenstones and their attendants.

3. The green-sand of the Mesabi iron-bearing formation appears to have resulted from a volcanic sand and the taconite itself from igneous forces.

Comment.—The three main petrological conclusions announced by Professor Winchell as the most important results of his final petrological work, summarized in the closing general paragraph, would be dissented from by most of the other geologists who have worked in this area.[1]

The Cambrian age of the Animikie strata has long been maintained by Professor Winchell, and above are summarized his arguments in support of this position. The first argument, that the Animikie grades into the Upper Cambrian rocks, is not in accord with the observations of most of the geologists above referred to. The second argument, based on the similarity of the unaltered green-sand in the Mesabi district with that in the Cambrian of the eastern United States, loses weight when we consider the fact that the similarity is not great, the differences being many and significant; and if the similarity were complete, the correlation would involve laying too much stress on lithological similarity of widely separated formations. Professor Winchell's latest conclusion, that the Mesabi green-sand is volcanic and not organic, while entirely dissented from by others who have studied this rock, in itself spoils his argument based on similarity. The third argument in favor of the Cambrian age of the Animikie, based on the extent of the unconformity beneath the Animikie, has little value when unsupported by the other lines of evidence. Professor Winchell's conclusion as to the Cambrian age of the Animikie strata is thus not adequately sustained by the reasons given. The view that the Animikie is Upper Huronian (pre-Cambrian) is the commonly accepted one. The evidence favoring this view is summarized by Van Hise.[2]

Further comment on the above work would require reference to the detailed observations made in northeastern Minnesota during the past four years by the Lake Superior Division of the United States Geological Survey.[1] The results of this work have not been published and any reference to the conclusions reached would be premature. In general it may be stated that now, as in the past, there is divergence in the conclusions reached by the Minnesota Survey and by the United States Geological Survey concerning the position and importance of the unconformities, correlation of series, and nomenclature.

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[1] Some of these geologists are: R. D. Irving, C. R. Van Hise, J. Morgan Clements, W. S. Bayley, U. S. Grant, J. E. Spurr, A. H. Elftman, C. K. Leith.

[2] Correlation Bulletin, Archean and Algonkian, No. 86, U. S. Geol. Survey; Principles of Pre-Cambrian Geology, Sixteenth Annual Report, U. S. Geological Survey.

C. K. LEITH.

The Norwegian Polar Expedition, 1893 to 1896. Scientific Results. Edited by FRIDTJOF NANSEN. Vol. I. Longmans, Green, & Co.

The object of the report of which this is the first volume is stated in the preface to be "to give in a series of separate memoirs a complete account of the scientific results of the Norwegian North Polar Expedition of 1893 to 1896." The first volume contains the following papers: "The Fram," 16 pp. with three plates; "The Jurassic Fauna of Cape Flora, Franz Josef Land," by J. F. Pompeckj, with a "Geological Sketch of Cape Flora and its Neighborhood," by Fridtjof Nansen, 147 pp. with three plates; "Fossil Plants from Franz Josef Land," by A. G. Nathorst, 26 pp. with two plates; "An Account of the Birds," by Collett and Nansen, 53 pp. with two plates; "Crustacea," by G. O. Sars, 137 pp. with thirty-six plates.

The fossil fauna brought back from Cape Flora was collected by Nansen during the period of his stay with Jackson at Elmwood, Cape Flora, Franz Josef Land. The collection was studied by J. F. Pompeckj, whose descriptions of the fossils constitute the second part of the volume. Collections from the same localities secured by the Jackson-Harmsworth expedition were examined and described by Mr. E. T. Newton, but the conclusions reached by Pompeckj and by Newton as to the age of the strata are somewhat at variance.

The condition of preservation of the fossils is poor, and many species, particularly of lamellibranchs, could not be identified even generically. The collection shows that a fauna of at least twenty-six different species occurs in the Jurassic sediments about Cape Flora.

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[1] The reports on this area in preparation by the survey are: Lake Superior Iron Ores, to appear in the Twenty-first Annual Report; Monograph on the Vermilion Iron Bearing District of Minnesota, and Monograph on the Mesabi Iron District of Minnesota.